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**BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES**

MAILED
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GROUP 1700

Application Number: 09/929,267
Filing Date: August 14, 2001
Appellant(s): PFEIFFER, HANS-WULF

Wesley Whitmyer
For Appellant

EXAMINER'S ANSWER

This is in response to the appeal brief filed 10/15/2007 appealing from the Office action mailed 3/29/2007.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of Claims

The statement of the status of claims contained in the brief is correct.

(4) Status of Amendments After Final

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of Claimed Subject Matter

The summary of claimed subject matter contained in the brief is correct.

(6) Grounds of Rejection to be Reviewed on Appeal

The appellant's statement of the grounds of rejection to be reviewed on appeal is correct.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

5,228,245	RICE	7-1993

3,573,023	THOMAS	9-1968
5,128,083	BROOKES	7-1992
6,153,023	ROKUTANDA	11-2000

The English-language abstract of JP 04108675, 9 April 1992

Kingery, W.D. "Introduction to Ceramics" 2nd ed. (1976) , John Wiley and Sons, pp. 3, 573-575.

[An English-language translation of JP 04108675 is attached to this Answer.]

(9) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

Claim Rejections - 35 USC § 112

The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

Claims 1-18 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

The MPEP sets forth what must be considered to establish whether the enablement requirement is met.

From **2164.01(a) Undue Experimentation Factors:**

There are many factors to be considered when determining whether there is sufficient evidence to support a determination that a disclosure does not satisfy the enablement requirement and whether any necessary experimentation is "undue." These factors include, but are not limited to:
(A) The breadth of the claims;
(B) The nature of the invention;
(C) The state of the prior art;
(D) The level of one of ordinary skill;
(E) The level of predictability in the art;
(F) The amount of direction provided by the inventor;
(G) The existence of working examples; and
(H) The quantity of experimentation needed to make or use the invention based on the content of the disclosure.

Examiner has considered these factors as follows:

(A) The claims are directed to all ceramic materials/workpieces –except for those which include zirconia. Thus the claim would encompass working on plate glass windows, common bricks, ceramic toilets, drinking glasses, enameled products, ceramets, carbon composites, false teeth, etc. In other words, the claims encompass a truly massive genus of materials. One would have to expect some universal material property to be present, in order for the invention to work on the entire <u>breadth of the claims</u>. It is noted that the genus is massive regardless of whether one used the broadest reasonable interpretation for 'ceramic' or an extremely narrow reasonable interpretation.

examiner does not agree with applicant's position that the claims are limited to "true ceramics" (whatever that would mean)

(B) The <u>nature of the invention</u> does not appear to lend itself as evidence to show the invention is not enabled.

(C) The state of the prior art is that applicant's invention cannot be done.

Applicant's specification is clear that the state of the prior art would be one where one would not expect to be able to use the invention, (starting on page 4, line 2 "neither been known nor been applied in practice without elevating the temperature…it is presumed that due to brittle characteristics the mechanical stress…results in damage – not an increase of the strength". And in [0010] ceramic "components would simply be too brittle for resisting the blast energy". [0011] states "[i]n general, brittle, hard materials such as ceramics are denied to have the ability to undergo a plastic deformation at room temperature." [0013] says indicates that the type of processing the claims are directed to, "can, as a matter of nature, not be expected in ceramic

materials". The Background section contains still further admissions which demonstrate with little doubt that one would expect that applicant's invention has no basis for enablement.

The prior art recognizes that Rice 5228245, indicates such processing will work only on "certain materials" (col. 1, line 18); namely, a very small niche – those that have hafnia or zirconia. Thomas 3573023 indicates that it is generally believed that surface hardening ceramics cannot be surface hardened (col. 1, lines 24-32), but does close 5 ceramics (col. 3, lines 38 and 53-55) , but two of these (glass and aluminum oxide) fall outside the claimed room temperature requirement.
The prior art recognizes the invention to work in very limited instances: e.g. those ceramic materials that are actually composites with metals – for example cermets; and specialized materials of the type discussed in Rice.

If the prior art says something can be achieved in only limited circumstances, and many people have tried to achieve it, it is a strong suggestion that it maybe impossible (except those limited instances. When the prior art suggests it cannot be done, there is a reasonable burden upon applicant to demonstrate that it can be done. Applicant assertion that it can be done (with no evidence to support such) is not very persuasive.

(D) The level of one of ordinary skill does not appear to lend itself as evidence to show the invention is not enabled.

(E) The level of predictability: the few examples in Rice and Thomas in the prior art shows unpredictability.

(F) The amount of direction provided by the inventor is low. There is no indication or suggestion as to what ceramics might work or what amount of force is needed to get the strengthening effect. The only thing indicated is that there is good direction on the type of tool needed (size and shape).

(G) There is no working example.

(H) The quantity of experimentation is unknown. The prior art indicates the invention would not work. Given that it was thought such could not be done, it seems that it is very, very difficult to determine the parameters required to make it work.

Given all the above factors, the references of record, and the specification, it is deemed the invention would require undue experimentation to use the invention, and claims are not commensurate in scope with the limit ceramic compositions for which the invention is enabled. That appellant solved a decades-old problem, that the problem is a problem that the prior art suggests cannot be solved except in a few instances, based on the "matter of nature", and that there is no evidence or examples provided that suggests that Applicant ever achieved the solution – it is deemed that a lack of enablement exists.

The specification does not enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the invention commensurate in scope with these claims.

It is reasonable to expect that such a method of making windows, plates, tiles (for homes and the space shuttle), sidewalks, etc. even stronger would likely be a multi-billion dollar invention. The implications appear astounding. Given the importance of such a revolutionary advance, it seem reasonable for the Office to ask Appellant to show that the invention works for the breadth of the claim.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 1-18 are rejected under 35 U.S.C. 103(a) as being unpatentable over Brookes in view of Thomas, Rokutanda, and the Abstract of JP 041098675.

Brookes teaches the basic claimed process of increasing the strength of workpieces manufactured of ceramic material comprising the steps of:

providing a workpiece, which does not comprise zirconia (col. 1, lines 7-9);

providing a tool having the same order of hardness as the workpiece (col. 1, line 57);

contacting the workpiece with the tool, (see col. 2, lines 5-7),

producing plastic deformation (col. 2, lines 47-48).

As to the shape of the tool: see col. 1, lines 47-48 and col. 2, line 62.

However, Brookes does not teach the diameter nor the temperature not elevated above room temperature. Thomas (at col .1 lines 54-60) suggests that surface hardening can occur at without temperature –control. Thus, it would have been obvious to perform the Brookes invention without controlling the temperature - i.e. at room temperature. One would immediately realize that avoiding a temperature controller and heating/energy costs would achieve cost savings and overall-simplification – thus providing motivation to modify the Brookes process.

Rokutanda discloses a tool (i.e. shot) for producing a point load as taught by Brookes. Rokutanda discloses that the diameter of the tool is less than 300 microns (col. 1, lines 34-35) and that such is conventional (col. 1, line 36). It would have been obvious to use such a conventional diameter because such would more easy to obtain than using or making an unconventional tool/shot. Alternatively: at col. 1, lines 24-28 Rokuntanda discloses that the size has an effect on the process, thus it is a result-effective variable. It would have been obvious to perform routine experimentation to determine the optimal shot size.

The Abstract of JP 04108675 discloses a process of shot peening, barrel polishing or honing the surface of a ceramic article (points of maximum stress or the whole surface) whereby improved strength a crack resistance is obtained. The abstract

discloses that shot peening can be applied to the whole surface, or points to be subjected to maximum stress; this would clearly suggests contacting the workpiece within a predetermined area that is less than the total surface area of the workpiece. It would have been obvious to one having ordinary skill in the art to treat only a portion of the Brookes workpiece in view of the teachings of the Abstract to obtain an article of desired configuration.

Claim 2: as discussed above, it would have been obvious to perform routine experimentation to determine the optimal value of the size of the shot.

Claims 3-4, 6 are clearly met.

Claim 5: It would have been obvious to use an automatic blaster/peener rather than a manual one, to save labor costs.

In re Venner, 262 F.2d 91, 95, 120 USPQ 193, 194 (CCPA 1958) (Appellant argued that claims to a permanent mold casting apparatus for molding trunk pistons were allowable over the prior art because the claimed invention combined "old permanent-mold structures together with a timer and solenoid which automatically actuates the known pressure valve system to release the inner core after a predetermined time has elapsed." The court held that broadly providing an automatic or mechanical means to replace a manual activity which accomplished the same result is not sufficient to distinguish over the prior art.).

It is inherent that such operates with air or else it operates without air.

Claims 7-9 are deemed to be covered by Brookes, col. 1, lines 45-46. It is noted that the claims imply a rather broad interpretation. Claim 1 requires the tool has a rounded contour and that the tool has the same order of magnitude of hardness. Most nails have a sharp point (not rounded). And one of ordinary skill would realize that typical nails and hammers do not have the same order of magnitude of hardness. Nails

and hammers have a steel of Mohr hardness around 6, and most ceramics have a hardness of greater than 7. The present specification does not describe what is meant by nail, hammer or roller. It would seem that the broad interpretation should include any structure that can roll, can hammer, or function as a nail.

Claims 10-18 are met for the reasons given above.

Claims 1-18 are rejected under 35 U.S.C. 103(a) as being unpatentable over Brookes, Thomas, or the Abstract of JP 041098675 in view of Rice.

Brookes, Thomas and the Abstract are treated as above. Rice is supplied as further evidence that other ceramics are known to be able to be surface hardened (see col. 2, lines 6-30). Rice teaches the process works with transformation toughened ceramics (col 3, lines 21-23). Although line 23-25 indicate that those with zirconia are "especially suitable", the plain reading is that transformation toughened ceramics that have no zirconia also work.

(10) Response to Argument

Factor A of the enablement rejection.

It is noted that Appellant has not disputed the finding that the claims encompass a massive genus of materials. Rather Appellant appears to wish to exclude composites and some other specialty materials from the scope of the claims. For simplicity sake: Appellant's position can be granted; the claims still encompass a massive genus including windows, common bricks, ceramic toilets, drinking glasses, etc.

For the sake of completeness of record: Examiner has noted Kingery (pages 3, 573-575) has been cited as identifying what one of ordinary skill considers to be covered by the term “ceramic”. And weighing the objective evidence of Kingery against the March 2004 Pfeiffer declaration, one would probably find that Kingery outweighs the evidence that comes from the Inventor who may have an interest in the weighing process. It is noted the declaration is incomplete - item 1 of the declaration refers to an attachment which was never received by the Office.

Factor B

Appellant argues that the specification discloses specifics. Examiner fails to understand how this relates to the “nature” of the invention. In a sense, “specifics" are the opposite of the ”nature” (i.e. the essence or character).

Factor C.

Appellant agrees with the Office's position that state of the prior art is one where one would not expect to be able to use the invention. It is argued that such is not evidence that the present method does not achieve the results described therein. This is not very relevant: factor C is simply a "factor" which must be considered. Moreover Examiner has not found that Appellant was not able to achieve the asserted results. If Examiner implied such, Examiner apologizes. Rather, the rejection is based on the finding that Appellant has not provided sufficient guidance to enable someone else (someone of skilled in the art) to make and use the invention as broadly claimed.

Factors D, E and G

Undisputed by Appellant.

Factor F

Examiner found that the amount of direction is low. Appellant disagrees - apparently because the specification has some specifics. As indicated in the analysis, Examiner considered there is some "good direction" related to the type and tool. Some "good" guidance does not mean that there is a large amount of guidance. Factor F is directed to the Amount of guidance. The analysis also found that there is no indication of what ceramics might work or the amount of force is needed; Appellant disagrees with this, but offers no explanation to support the disagreement.

Appellant does assert the [0031] "static ball thrust test" is used to achieve the invention. This test comes from an unknown foreign publication - which never was provided to the Office. Since there is no evidence which shows this document enables the invention, it is taken to be just argument. Furthermore at the second line of [0031] it is indicated that such is merely "preferable" – one would conclude that this is not the new discovery which permits one to do what has been found to be impossible.

Factor H

Appellant argues that the static ball thrust tests are well known. The relevance of this is unclear. The factor relates to the "quantity" of testing, not whether a specific

test is known. Moreover [0031] at line 2 refers to two experiments, but only one test appears to be described. That second (undisclosed) test may be a massive test, it may take 20 years, or it might be a simple 5 minute test. It is simply unknown.

It is noted that Appellant has contested the individual factors, but has not disputed whether the ultimate conclusion that the factors (A-H), references of record and the specification, when taken together demonstrate that the first paragraph of 35 USC 112 is complied with.

103 Rejection.

It is argued that Thomas fails to teach impacting a true ceramic without first elevating the temperature of the workpiece. This is not very relevant because the claims are not limited to "true ceramics".

It is also argued that Thomas teaches aluminum oxide requires elevated temperatures. This is not very relevant. The rejection is not based on aluminum oxide. Thomas teaches other ceramics can be treated at room temperature. Brookes covers many materials that do not have aluminum oxide (col. 1, lines 7-10).

It is further argued that Thomas teaches that the "true ceramics" require elevated temperatures. However Appellant has never pointed out where this supposed teaching is in Thomas, nor can Examiner find such. Thomas only indicates a subgenus that requires elevated temperatures: those comprising aluminum oxide. It is silent as to the rest of the genus.

Appellant also argues that the "near ceramics" (cermets) of Thomas is not a ceramic. First of all, on face value, the term "near ceramic" has the word "ceramic" in it - thus there is a presumption that it is a ceramic. Second, the Kingery textbook references indicates that cermets are ceramics - and Appellant has not pointed out why Kingery – along with his two co-authors (all professors of Ceramics at MIT) were incorrect in indicating that cermets are ceramics. Third, the Pfeiffer declaration does not appear to be very relevant, there is no indication that Pfeiffer has any expertise in the area of ceramics. Pfeiffer only attests to having experience with "brittle hard materials"; those materials may be metal alloys. See Rokutanda (col. 1, lines 9-10). Also, it is unclear whether the term "ceramic" means different things in different countries. Since declarant is/was a citizen of Germany, it may be that declarant can only speak to how the term is used in Germany. Examiner will agree that declarant's definition is a reasonable definition, however it is not the <u>broadest</u> reasonable definition. Thus the declaration by Pfeiffer fails to surmount the evidence. Lastly, examiner cannot find anything in the specification which suggests that the term "ceramic" should (or might) be limited to exclude the Thomas ceramics.

It is also argued that Brookes teaches that temperature has to be controlled, and refers to the 0.3Tm- 0.5Tm range for temperatures. This is not convincing because the passage indicates that it is "usually" in that range (Thomas, col. 2, line 32) for all cermic compositions. Thus one would understand the temperatures are not necessarily in that range. This is entirely consistent with the teachings of Thomas at col. 3, lines 57-61 which indicates sometimes temperature control is necessary, and sometimes it isn't.

Brookes is completely silent as to those instances which are not in the usual 0.3 Tm-0.5 Tm range. One of ordinary skill having the teachings of both Brookes and Thomas would understand that there are some ceramics (e.g. tungsten carbide) need not have the control be at an elevated temperature.

Regarding the rejection which relies on Rice, Appellant correctly points out that Rice does not point out any specific ceramic which does not contain zirconia. This argument is not well taken because Appellant also does not point out any specific ceramic which does not contain zirconia. Moreover col. 3, lines 20-26 of Rice clearly state that _ANY_ transformation toughened material can be treated. Those that are ceramics are "particularly suitable". And those that have zirconia are "especially suitable".

Disclosed examples and preferred embodiments do not constitute a teaching away from a broader disclosure or nonpreferred embodiments. In re Susi, 440 F.2d 442, 169 USPQ 423 (CCPA 1971). "A known or obvious composition does not become patentable simply because it has been described as somewhat inferior to some other product for the same use." In re Gurley, 27 F.3d 551, 554, 31 USPQ2d 1130, 1132 (Fed. Cir. 1994) (The invention was directed to an epoxy impregnated fiber-reinforced printed circuit material. The applied prior art reference taught a printed circuit material similar to that of the claims but impregnated with polyester-imide resin instead of epoxy. The reference, however, disclosed that epoxy was known for this use, but that epoxy impregnated circuit boards have "relatively acceptable dimensional stability" and "some degree of flexibility," but are inferior to circuit boards impregnated with polyester-imide resins. The court upheld the rejection concluding that applicant's argument that the reference teaches away from using epoxy was insufficient to overcome the rejection since "Gurley asserted no discovery beyond what was known in the art." 27 F.3d at 554, 31 USPQ2d at 1132.). Furthermore, "[t]he prior art's mere disclosure of more than one alternative does not constitute a teaching away from any of these alternatives because such disclosure does not criticize, discredit, or otherwise discourage the solution claimed...." In re Fulton, 391 F.3d 1195, 1201, 73 USPQ2d 1141, 1146 (Fed. Cir. 2004).

It is also argued that one would not combine Brookes and Thomas with Rice's room temperature, because Brookes and Thomas teach otherwise. It is not very relevant that Brookes and Thomas teach elevated temperatures, because (as pointed out above) they also suggest elevated temperatures are only necessary for some materials. When one considers all the references one would immediately understand that Rice discover a limited subgenus of ceramics which avoids the need to heat.

. On the contrary, if the prior art says something cannot be achieved and many people have tried to achieve it, it is a strong suggestion that it maybe impossible. When the prior art suggests it cannot be done, there is a reasonable burden upon applicant to demonstrate that it can be done. Applicant assertion that it can be done (with no evidence to support such) is insufficient.

Regarding F) The amount of direction provided by the inventor. The arguments made by applicant are not understood, or at least not very relevant. As indicated above, Examiner concluded that the amount of direction provided was "low" because it does not indicate/suggest what ceramics might work. Applicant has not pointed out how the amount of direction was not "low". Whereas applicant points out that cermets and cemented carbides would not work, this is not the same thing as pointing out what would work. Even a teaching that two types of ceramics would not work would still rate a "low" amount of direction.

(11) Related Proceeding(s) Appendix

No decision rendered by a court or the Board is identified by the examiner in the Related Appeals and Interferences section of this examiner's answer.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

John Hoffmann/

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PRIMARY EXAMINER
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1/4/08

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Japanese Patent
Document No. 4-108675

CERAMIC-METAL JOINED STRUCTURE

[Seramikkusu-Kinzoku Setsugo Tai]

Shun'ichiro Tanaka

UNITED STATES PATENT AND TRADEMARK OFFICE

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English Title	:	CERAMIC-METAL JOINED STRUCTURE

Specification

1. Title of the invention

CERAMIC-METAL JOINED STRUCTURE

2. Patent Claims

1. A ceramic-metal joined structure with the following characteristics: In a joined structure of a ceramic component and a metal component, the surface of the aforementioned ceramic component has been subjected to a stress reduction treatment wherein a non-directional compressive stress is impressed by means of mechanical processing.

2. A ceramic-metal joined structure with the following characteristics: In a joined structure of a ceramic component and a metal component, the surface of the joined structure which includes the maximal principal stress point of said joined structure has been subjected to a stress relief treatment whereby an energy beam is irradiated.

3. Detailed explanation of the invention

[Objective of the present invention]

(Industrial application fields)

The present invention concerns a ceramic-metal joined structure obtained by joining a ceramic component and a metal component.

[1] Numbers in the margin indicate pagination in the foreign text.

(Prior art)

Ceramics are peculiarly characterized by light weights and high hardnesses, and accordingly, high strengths and abrasion resistances ascribed to such hardnesses are being actively utilized.

The excellent attributes of the ceramics, furthermore, become manifest in a high-temperature region of 1,000 C or higher. The respective heat resistances of silicon nitride and silicon carbide, for example, are nearly 1,200 C and 1,500 C, and therefore, in cases where they are applied to temperature regions that cannot be tolerated by metals, significantly improved heat efficiencies can be expected.

Since the ceramics are inherently brittle materials, however, it is difficult to use them alone, and it is more rational to rely on a method wherein a ceramic is used only in a site that must meet a performance requirement based on its combination with another material.

As far as such techniques for joining ceramics are concerned, a method which relies on mechanical coupling or an organic adhesive and a chemical joining method which is accompanied by some type of reaction (e.g., interfacial diffusion of constituent elements, solid solution, formation of reaction product, etc.) have been attempted.

As for methods for chemically joining ceramics, a solid phase joining method wherein direct joining is performed without recourse to intervening matters or an activated metal method which uses an

insert material that can be easily reacted with a ceramic /2 are mainstream options in the case of structural ceramics, whereas the metallizing method is being utilized for semiconductor substrates, etc.

In a case where silicon nitride, which is a representative example of structural ceramics, is joined with a metal component, for example, a method wherein an activated metal such as Ti, etc. is permitted to intervene and wherein the respective members are joined by using a co-crystal with said activated metal and a metal soldering method wherein a rollable metal that qualifies as a buffer (normally Cu, etc.) is configured between a ceramic and a metal for alleviating the joining stress and wherein the respective members are joined via a soldering material such as Ag-Cu-Ti, etc. are being used frequently.

(Problems to be solved by the invention)

The thermal expansions of the ceramics, however, are less than those of metals, and in particular, the corresponding magnitudes of sodium nitride and silicon carbide, which are useful as structural ceramics by virtue of their high heat resistances, are extremely low.

For this reason, a residual stress attributed to a thermal expansion differential becomes generated during a post-joining cooling process in the context of joining the ceramic and metal material, and it serves as a factor contributing to the arisings of various problems.

In other words, a high residual stress becomes generated in the vicinity of a joined portion, especially in the vicinity of a cardinal point in the junction interface, and in such a case, the joining strength may diminish greatly due to its synergistic effect with an external stress, or cracks may become generated from the maximal stress point of a post-joining cooling process or heat cycle, leading often to the destruction of the ceramic.

It has become urgent in the current state thus characterized to provide a ceramic-metal joined structure which is capable of exploiting the excellent characteristics of a ceramic by reducing the residual stress on the ceramic surface and by improving the joining strength between ceramic and metal components.

The objective of the present invention, which has been conceived for solving the foregoing problems, is to provide a sound and stable ceramic-metal joined structure wherein the joining strength between ceramic and metal components is high and which is unaccompanied by cracking, etc.

[Constitution of the invention]

(Mechanism for solving the problems)

The ceramic-metal joined structure of the first of the present inventions is a joined structure of a ceramic component and a metal component, and it is characterized by the fact that the surface of the aforementioned ceramic component has been subjected to a stress reduction treatment

wherein a non-directional compressive stress is impressed by means of mechanical processing.

The ceramic-metal joined structure of the second invention is a joined structure of a ceramic component and a metal component, and it is characterized by the fact that the surface of the joined structure which includes the maximal principal stress point of said joined structure has been subjected to a stress relief treatment whereby an energy beam is irradiated.

Mechanical processing methods such as barrel polishing, shot peening, honing, etc. are conceivable as methods for executing the stress reduction treatment in the first invention, and a joined and/or yet-to-be-joined ceramic component is subjected to a stress reduction treatment wherein a non-directional compressive stress is impressed by means of such mechanical processing.

The stress reduction treatment may be performed over the entire plane of the ceramic component, or it may be locally performed on a segment which receives maximal stress.

Such a ceramic component which bears a non-directional compressive stress in its interior is capable of reducing a tensile stress generated on the surface of the ceramic while it is being joined with the metal component, and accordingly, a ceramic-metal joined structure characterized by a healthy joined state can be obtained.

Energy beams which are used for the stress relief treatment of the second invention are instantiated by microscopic energy beam fluxes of electron beams, far infrared rays, laser beam, ion beam, SOR beam, X rays, etc.

These energy beams are irradiated locally on a site which includes the maximal principal stress point of the surface of the ceramic-metal joined structure, and they may be irradiated on joining sites which include maximal principal stress points and which are confined to the ceramic component side alone, confined to the metal component side alone, or which encompass both the ceramic component and metal component which sandwich the junction interface of the joined structure.

As far as the present invention is concerned, an annealing effect is achieved as a result of the irradiations of these energy beams. The annealing modality represents a treatment method wherein the residual stress of a molded product is reduced by heating a raw material over an extended period at a temperature lower than its thermal deformation point, and as far as the present invention is concerned, the irradiation period at 500 ~ 800 C is designated at 0.3 ~ 2 hours with regard to a silicon nitride ceramic component, whereas it is desirable for the irradiation period at 400 ~ 600 C to be designated at 0.1 ~ 5 hours in a case where the irradiation target encompasses/3 a silicon nitride ceramic and a steel material.

The residual stress of the joined structure attributed to the thermal expansion differential during the joining operation can be alleviated and relieved as a result of such a stress relief treatment based on the energy beam irradiation.

A local treatment, in particular, is effective in that the cost can be lowered without adversely affecting the properties of the respective constituent components.

There are no special restrictions, furthermore, on the ceramic components and metal components to be used in the present invention, and the ceramics are instantiated by silicon nitride, silicon carbide, alumina, zirconia, SIALON, etc., whereas ones that constitute various components such as steel materials, copper sheets, heat-resistant alloys, superhard alloys, pure metals (e.g., Y, Mo, Ni, etc.), etc. are usable as metals.

(Functions)

An example of the residual stress distribution of a ceramic-metal joined structure is shown in Figure 9.

Measurement results on the Si_3N_4 section of a flat sheet-shaped Si_3N_4-Cu-steel joined structure (Cu is permitted to intervene as a buffer) are hereby shown, where Figures 9 (a) and (b) show the distributions of vertical stresses and shear stresses on lines detached from the junction interface via y = 0.1 mm and y = 0.5 mm, respectively.

The respective vertical stresses of $_{Rx}$ and $_{Ry}$ each serve as tensile stresses at both far ends of the joined structure, namely its cardinal points, and in particular, a high value that exceeds 200 MPa is exhibited by $_{Ry}$.

In other words, as Figure 10 indicates, this tensile stress signifies that a high stress is exerted along a direction perpendicular to the junction interface A between the ceramic component (1) and metal component (2) (direction of arrow Y).

In contrast, the ceramic-metal joined structure of the first invention is obtained by subjecting a yet-to-be-joined ceramic component to a stress reduction treatment by means of mechanical processing, as a result of which a non-directional compressive stress becomes impressed on the ceramic component.

The ceramic-metal joined structure of the second invention, furthermore, is obtained by subjecting the surface of a joined structure that includes a post-joining maximal principal stress point to a stress relief treatment wherein an energy beam is irradiated, based on which a sound joined structure can be provided by relieving the residual stress.

The residual stresses of the ceramic-metal joined structures are reduced by these means, as a result of which their joining strengths are improved.

(Application examples)

Next, application examples of the present invention will be explained.

Application Example 1

Figure 1 is a diagram which shows the ceramic-metal joined structure of an application example of the present invention.

The ceramic-metal joined structure (11) shown in the same figure is obtained by joining the silicon nitride ceramic (12) (cross-sectional size: 12 mm x 12 mm; length: 20 mm) and the identically sized S34C steel material (13) based on the activated metal soldering method, and the surface of the silicon nitride ceramic (12) has been subjected to a stress reduction treatment based on a barrel polish.

This ceramic-metal joined structure (11) is prepared according to the following procedures.

First, the entire plane of the silicon nitride ceramic (12) is subjected preliminarily to a barrel polish at a rotation frequency of 100 rpm over a polishing period of 1 hr by using a wet centrifugal barrel polishing machine. The surface roughness of the silicon nitride ceramic (12) became Rmax = 4 μm as a result of this stress reduction treatment, and a non-directional compressive stress of 80 MPa was impressed on it.

Next, this silicon nitride ceramic (12) and S34C steel material (13) were mutually joined by the activated metal

soldering method in a vacuum at 830 C for 6 min. while Cu was being employed as a buffer.

The bending strength of the ceramic-metal joined structure of this application example was measured, as a result of which 370 MPa was ascertained.

For comparative purposes, on the other hand, a ceramic-metal joined structure was prepared without subjecting the silicon nitride ceramic to a barrel polish under conditions otherwise identical to those of this application example, and its bending strength was measured. As a result, the value of this comparative example was as low as 320 MPa.

Application Example 2

Figure 2 is a diagram which shows the ceramic-metal joined structure of another application example of the present invention.

The ceramic-metal joined structure (21) shown in the same figure is obtained by joining the silicon nitride ceramic (22) (cross-sectional size: 10 mm x 3 mm; length: 20 mm) and the identically sized SUS 804 material (23) /4 based on the activated metal soldering method, and the surface of the silicon nitride ceramic (22) has been subjected to a honing stress reduction treatment.

This ceramic-metal joined structure (21) is prepared according to the following procedures.

First, the silicon nitride ceramic (22) is subjected preliminarily to a wet honing treatment based on the use of

glass beads under the following conditions: Blow rate from a nozzle with a diameter of 0.5 mm: 100 g/min.; blow velocity: 15 m?/sec.

The surface roughness of the silicon nitride ceramic (22) became Rmax = 8 ìm as a result of this stress reduction treatment, and a non-directional compressive stress of 120 MPa was impressed on it.

Next, this silicon nitride ceramic (22) and SUS 804 material (23) were mutually joined by the activated metal soldering method in a vacuum at 830 C for 6 min.

The bending strength of the ceramic-metal joined structure of this application example was measured, as a result of which 150 MPa was ascertained.

For comparative purposes, on the other hand, a ceramic-metal joined structure was prepared without subjecting the silicon nitride ceramic to honing under conditions otherwise identical to those of this application example, and its bending strength was measured. As a result, the joined structure of this comparative example became cracked in the vicinity of the junction interface of the two components, and a defective sample which was unusable as a product was obtained.

<u>Application Example 3</u>

Figure 3 is a diagram which shows the ceramic-metal joined structure of still another application example of the present invention.

The ceramic-metal joined structure (31) shown in the same figure is a joined structure wherein the S45C steel material (33) (cross-sectional size: 20 mm x 3 mm; length: 3 mm) is sandwiched between the silicon nitride ceramics (32a) and (32b) (cross-sectional size: 20 mm x 3 mm; length: 20 mm).

The copper sheet (34) is inserted as a buffer material into the gap between the silicon nitride ceramics (32a) and (32b) and the S45C steel material (33).

The vicinity of the junction interface, which is centered around the copper sheet (34) and which encompasses the silicon nitride ceramics (32a) and (32b) and S45C steel material (33), has been subjected to a stress relief treatment based on laser beam irradiation.

This ceramic-metal joined structure (31) was obtained by initially joining the respective constituent components by an ordinary method and by locally subjecting the vicinity of the junction cardinal point of said joined structure (inclusive of the maximal principal stress point) as well as the peripherals of the center of its junction interface to annealing while 5 KV CO_2 laser beams were being irradiated onto a total of 5 sites (diameter: 2.0 mm) over a 5-min. period.

As Figure 4 indicates, the maximal principal stress point manifests at a site approximately 0.5 mm into the silicon nitride side from the junction interface of Cu, namely a buffer metal, and silicon nitride, along the axial direction of both ends of the junction, and the laser irradiation target is designated to include this site.

After such a stress relief treatment had been performed, the residual stress distribution on the maximal principal stress line along the aforementioned junction interface was measured. As a result, the residual stress value at the maximal point was ascertained to be 120 MPa.

The maximal principal stress value of a case where no laser beam was irradiated, on the other hand, was 310 MPa.

These results are shown in Figure 5. The results of the application example are indicated by the solid curve, results the results of the comparative example are indicated by the dotted curve.

Application Example 4

Figure 6 is a diagram which shows the ceramic-metal joined structure of still another application example of the present invention.

The ceramic-metal joined structure (41) shown in the same figure is obtained by joining the Cu sheet (43) atop the alumina substrate (42) based on the DBC method.

The respective corners of the Cu sheet (43) were annealed by scanning and irradiating 5 KV CO_2 laser beams

(diameter: 1.5 mm) for 10 min. each, as is indicated by (44) in Figure 6.

The treated sample tolerated a subsequent heat shock test (300 C underwater quenching at 0 C).

In contrast, an unannealed sample was accompanied by the peeling of the Cu sheet.

Application Example 5

Figure 7 is a diagram which shows the ceramic-metal joined structure of still another application example of the present invention.

The ceramic-metal joined structure (51) shown in the same figure is obtained by joining four Cu sheets (53) atop the aluminum nitride substrate (52) in a straggling manner based on the direct joining method.

3 KV YAG laser beams were irradiated on the respective corners of said Cu sheets (53) as spots with a diameter of 2 mm over a 20-min. period during a local annealing /6 treatment.

The aluminum nitride substrate which had thus been subjected to the stress relief treatment and an aluminum nitride substrate which had not been subjected to the stress relief treatment were each subjected to heat cycle tests.

As a result, the life of the substrate which had been irradiated with the laser beam was twice as long as that of the unirradiated substrate.

Application Example 6

Figure 8 is a diagram which shows the ceramic-metal joined structure of still another application example of the present invention.

The ceramic-metal joined structure (61) shown in the same figure has been irradiated with far infrared rays.

This represents a PGA of an AlN 8-layer structure, and after the AlN had been metallized, it was subjected to Ni plating and Ag soldering treatments, and subsequently, the KOV lead (62) was joined with it. The peripherals (63) of the junction interface were irradiated with far infrared rays, and in comparison with its untreated counterpart, no defects such as AlN fractures, etc. were incurred.

In the same figure, furthermore, (64) shows a magnified view of the peripherals (63) of the junction interface, where the annealed segment (65) exists concentrically around the KOV lead (62).

As these results clearly indicate, as far as the ceramic-metal joined structure which has been subjected to a stress reduction treatment or stress relief treatment is concerned, the non-directional compressive stress impressed on the ceramic component is capable of absorbing and alleviating the residual stress attributed to the thermal expansion differential during the joining of the joinable components, and furthermore, the post-joining stress of the joined structure which bears a residual stress can be alleviated by a partial annealing treatment which uses an

energy beam, based on which the joining strength can be improved.

(Effects of the invention)

As the foregoing explanations have demonstrated, as far as the ceramic-metal joined structure of the present invention is concerned, a non-directional compressive stress may be impressed on the surface of a ceramic component, or a site of the joined structure which includes a maximal principal stress point may be irradiated with an energy beam, as a result of which the joining strength of the joined structure can be improved by alleviating the residual stress generated in it, and a sound ceramic-metal joined structure with a minimal defect (e.g., crack, etc.) generation frequency can be obtained.

4. Brief explanation of the figures

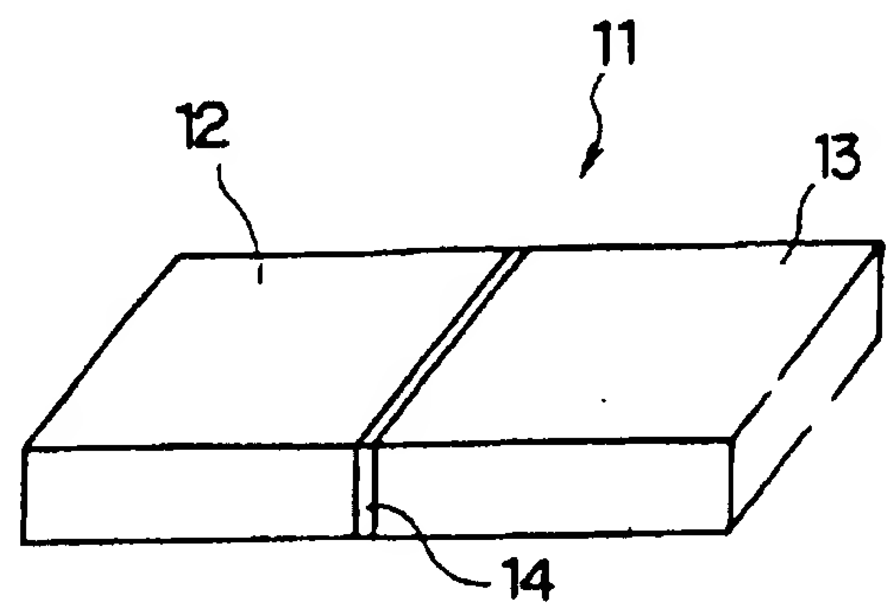
Figure 1 is a diagram which shows the ceramic-metal joined structure of an application example of the present invention, whereas Figures 2 and 3 are each diagrams which show the ceramic-metal joined structures of other application examples, whereas Figure 4 is a diagram which shows the planewise distribution of the maximal principal stress points in the vicinity of the junction interface, whereas Figure 5 is a diagram which shows the measurement results on the residual stress distribution of the ceramic-metal joined structure, whereas Figures 6 through 8 are each diagrams which show the ceramic-metal joined structures of

still other application examples, whereas Figure 9 is a diagram which shows an example of the residual stress distribution of a ceramic-metal joined structure of the prior art, whereas Figure 10 is a diagram provided for explaining the ceramic-metal joined structure of the prior art.

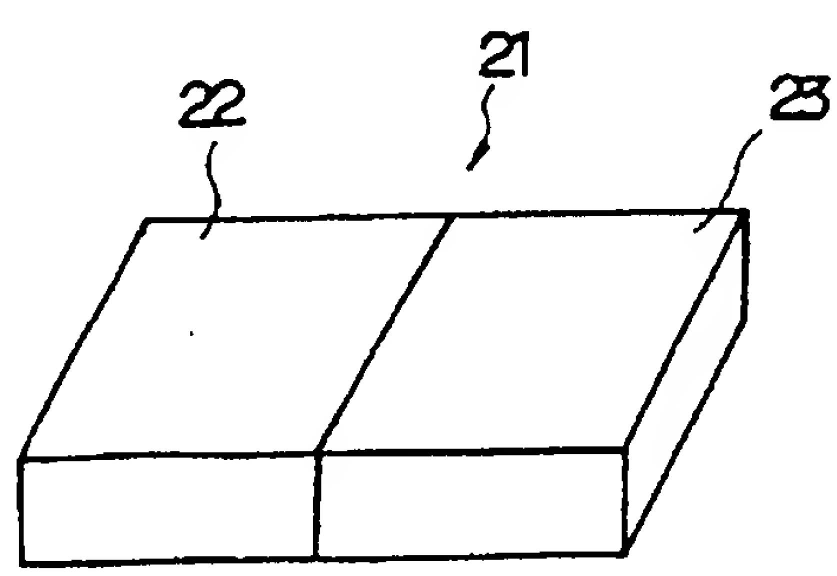
(11) and (21): Ceramic-metal joined structures; (12) and (22): Silicon nitride ceramics; (13) and (23): Metal components; (34): Copper sheet; (35): Irradiation spot; (42): Alumina substrate; (43): Copper sheet; (52): Aluminum nitride substrate; (61): Ceramic-metal joined structure; (A): Junction interface.

Applicant: Toshiba Corp.

Agent: Saichi Suyama, patent attorney



第 1 図



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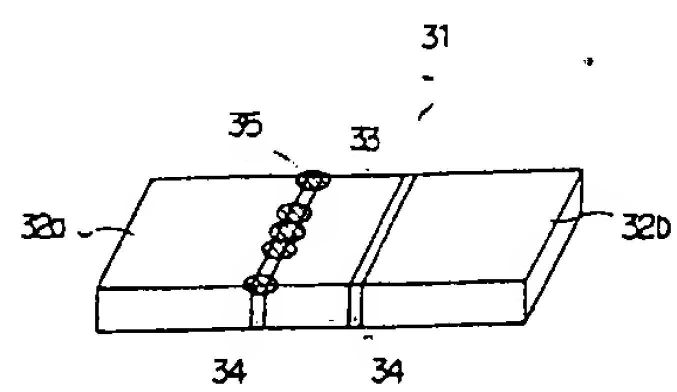

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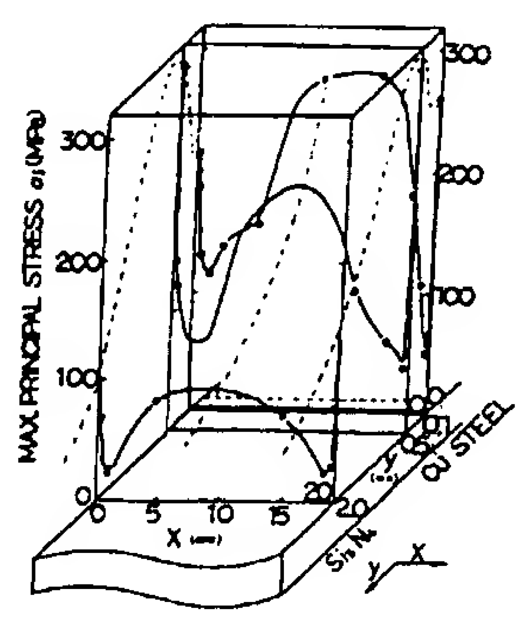

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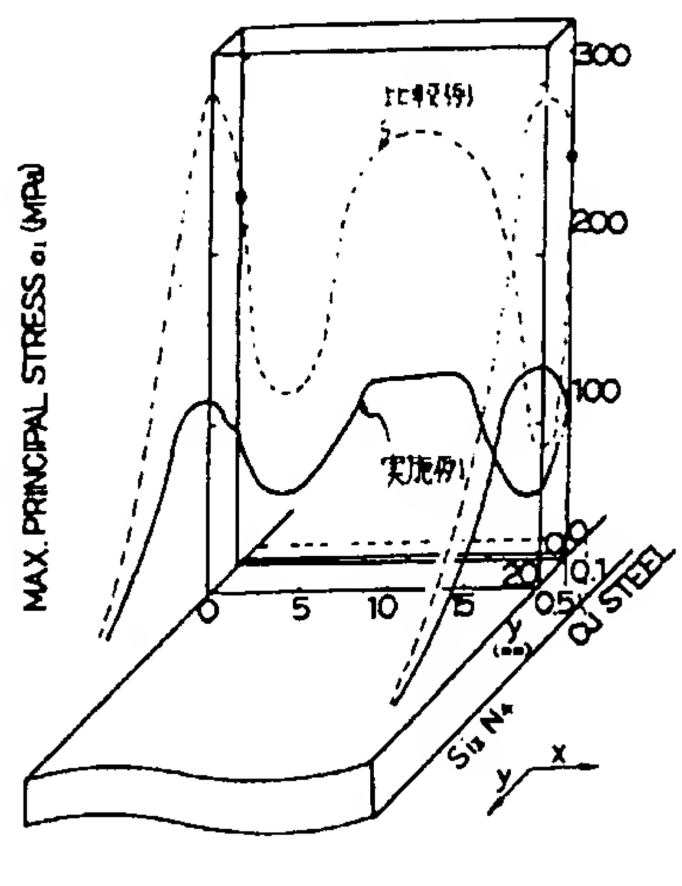
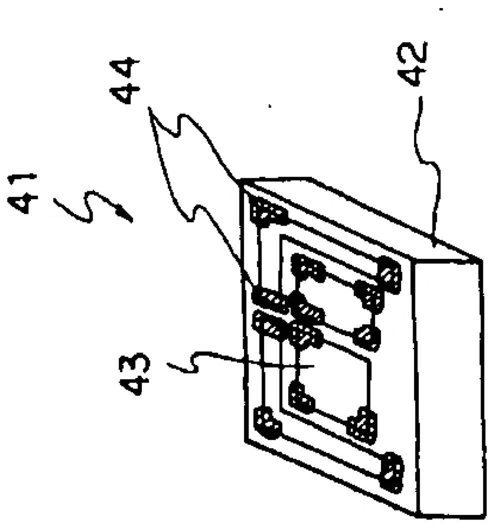


第 5 図

/6



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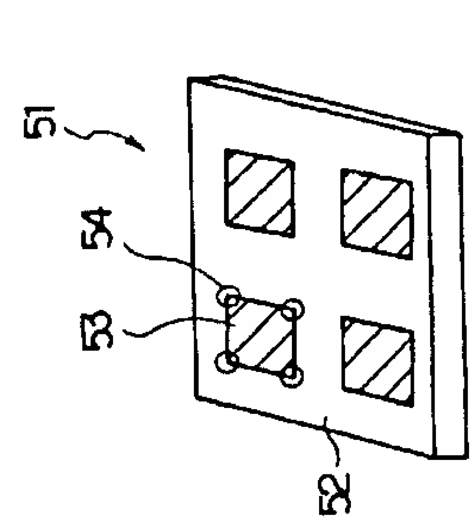

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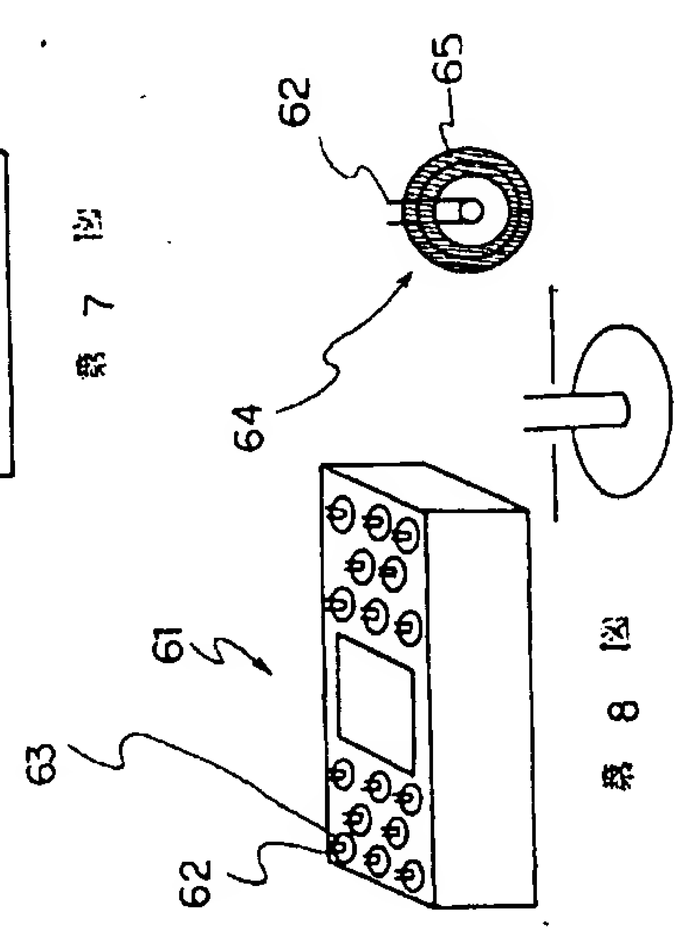

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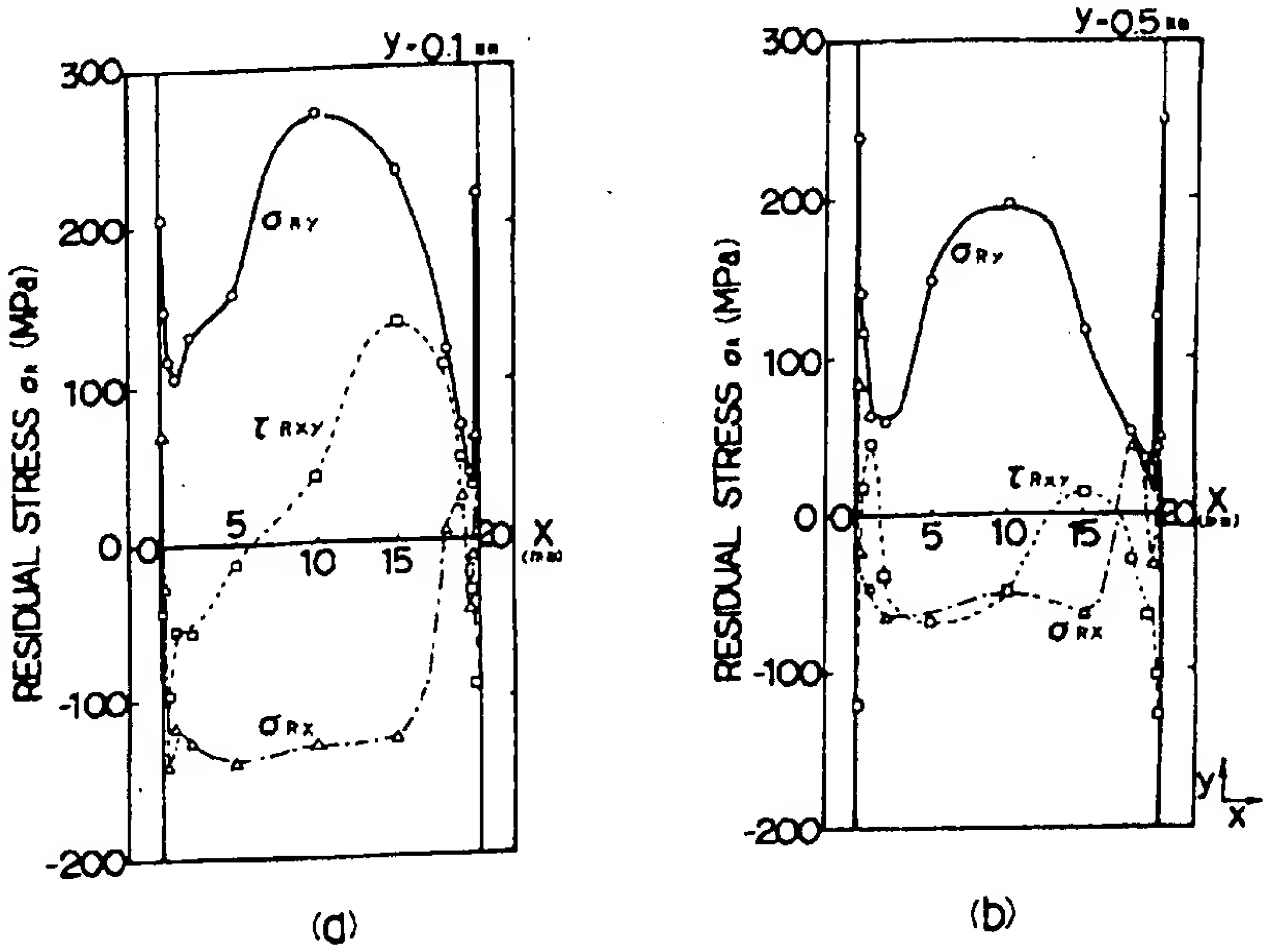
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X
(a)
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300
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τRXY
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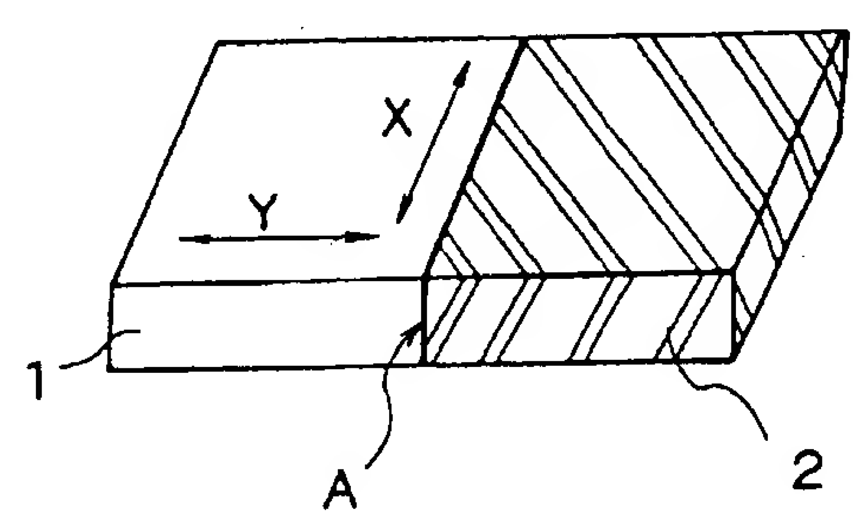
10
15
20
X
(b)

/7

第 9 図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Y
1
A
2

第 10 図